Pledge for a transformative science: a conceptual framework

Schneidewind, Uwe; Singer-Brodowski, Mandy; Augenstein, Karoline; Stelzer, Franziska

Veröffentlichungsversion / Published Version
Arbeitspapier / working paper

191_Wuppertal Paper | Wuppertal, July 2016

Pledge for a Transformative Science

A conceptual framework

Uwe Schneidewind, Mandy Singer-Brodowski, Karoline Augenstein and Franziska Stelzer

ISSN 0949-5266

Wuppertal Institut

Publisher:

Wuppertal Institute for Climate, Environment and Energy
Döppersberg 19
42103 Wuppertal
Germany

www.wupperinst.org

Authors:

Uwe Schneidewind, Mandy Singer-Brodowski, Karoline Augenstein and Franziska Stelzer

E-Mail: uwe.schneidewind@wupperinst.org

Pledge for a Transformative Science

“Transformative science“ is a concept that delineates the new role of science for knowledge societies in the age of reflexive modernity. The paper develops the program of a transformative science, which goes beyond observing and analyzing societal transformations, but rather takes an active role in initiating and catalyzing change processes. The aim of transformative science is to achieve a deeper understanding of ongoing transformations and increased societal capacity for reflexivity with regard to these fundamental change processes. The concept of transformative science is grounded in an experimental paradigm, which has implications for (1) research, (2) education and learning, and (3) institutional structures and change in the science system. The article develops the theoretical foundations of the concept of transformative science and spells out the concrete implications in these three dimensions.

Contents

1 What is the new role of science in an age of reflexive modernity?

The relationship between science and society has changed fundamentally in modern knowledge societies over the past decades. The functional differentiation of modern societies (Giddens 1984; Beck 1986) into highly specialized, autonomous sub-systems, each characterized by a specific logic, routines and codes, has been the basis for enormous increases in effectiveness and efficiency of affluent societies. At the same time, this process has resulted in a system where its various sub-systems are more and more isolated from each other. Technological development, especially in the field of information and communication technologies, has further increased disembedding mechanisms (Giddens 1996, 37) where, for instance, different groups of actors can coordinate their relationships and actions independent of spatial proximity.

Processes of social disembedding in modern societies have an impact on individual patterns of perception as well as political and institutional negotiation processes. This development has been catalyzed by technological innovations that have been the result of scientific knowledge-production. Especially critical are those types of technological innovations that deeply interfere with natural and human systems (Grunwald 2008) and produce unintended and often irreversible ecological and social side effects (Beck 1986). Long-standing research in the field of technological impact assessment as well as the more recent emergence of Responsible Research and Innovation (RRI) (von Schomberg 2011; Guston et al. 2014) show that the development of controversial technologies (e.g. nanotechnology or GeoEngineering) should be accompanied by reflection and discursive deliberation, involving different societal stakeholders, of advantages and disadvantages, potential and risks of a specific technology. Many modern technologies that have been developed primarily by scientists have been an important element in the depletion of natural resources and allowed us to exceed planetary boundaries (Rockström et al. 2009; Steffen et al. 2015). The example of man-made climate change as a "super wicked problem" (Levin et al. 2012) shows that humanity in the anthropocene (Crutzen 2002) is not only facing the challenge of reducing environmental risks, but much rather has to find a way of dealing with interdependent social-ecological transformation processes and learn how to organize societal systems differently.

Scientific knowledge production can thus be understood as an exploratory search process in complex systems characterized by uncertainty and unpredictable dynamics. Already in 1993, Funtowicz and Ravetz coined the term post-normal science, which accounts for systemic uncertainty by integrating different and often conflicting interests and interest groups in an "extended peer community" (1993, p. 752). Similarly, approaches of a mode-2 science (Gibbons 1999; Nowotny et al. 2001; Nowotny 2003) build on the assumption that in modern knowledge societies, knowledge is produced by a variety of actors in different settings. It is argued that a "re-contextualization" of science (Rip 2011, p. 5) is needed in order to adequately deal with the complexities of knowledge production in the age of reflexive modernity.

The idea of a reflexive modernity (Beck et al. 1996) can be linked to a new understanding of the role of science: Science in the age of reflexive modernity is an institutionalized sub-system of society whose task it is to analyze societal dynamics and challenges, while at the same time builds on a normative demand for proactively dealing with these challenges and contributing to a more sustainable development (Reid et al. 2010). In order to increase reflexivity in dealing with great societal challenges and to re-integrate societal sub-systems, science needs to transcend its descriptive analytical functions and cooperate with non-academic actors to achieve shared, normative goals.

1.1 Innovation, Participation and Balancing Power

The idea of transformative science builds on these observations and describes a concept of science that is not just another highly specialized sub-system of society, but rather a societal institution that can counter the dysfunctional effects of increasing differentiation and dis-embedding (Schneidewind/Singer-Brodowski 2014, p. 92 f.). Four inherent societal functions of the science system play a role in this respect: (1) increasing *reflexivity* in societal processes, (2) broadening the solution space and scope for action through social and technological *innovations*, (3) strengthening *participation and self-organization* in modern societies, (4) facilitating processes of *balancing societal power structures* through the legitimizing force of evidence-based arguments.

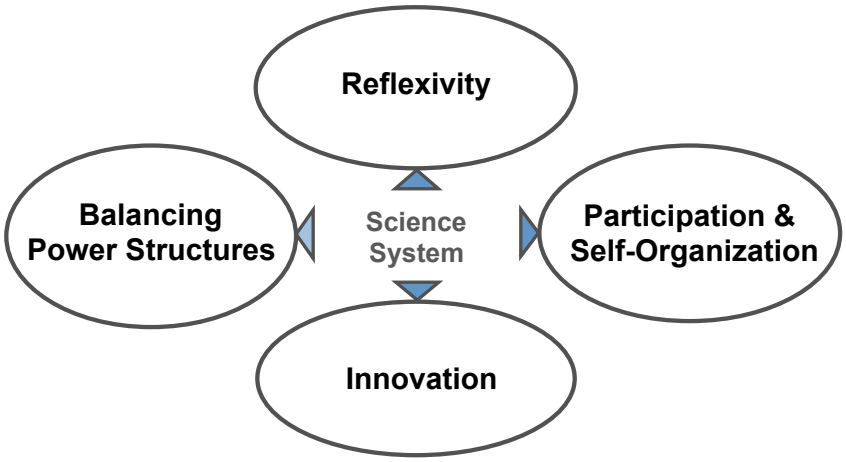

Fig. 1: How science contributes to institutional stabilization in an age of reflexive modernity (Schneidewind/Singer-Brodowski 2014, 93 based on Minsch et al. 1998)

(1) Reflexivity

Reflexivity is the key concept in Beck's and Giddens' analyses of modern knowledge societies: societies in an age of reflexive modernity are continually learning societies. Individual control as well as collective governance is based on scientifically sound and evidence-based arguments. The meaning and societal relevance of science is thus closely tied to its reflexive capacities. Popa et al. define reflexivity in modern societies as a "collective process of problem framing and problem solving through joint experimentation and social learning that directly involve the scientific and extra-scientific expertise" (2014, p. 45). Science can thus be an enabler of collective social learning processes.

(2) Participation

A direct link can then be established with the participative function of science in society. Science can catalyze social learning processes especially where societal actors are integrated in research and knowledge production processes early on. Participation can take the form of "co-design", i.e. joint framing of research questions and development of research designs, as well as "co-production", i.e. joint knowledge production (Mauser et al. 2013, Grunwald 2013). Examples of "co-design" can be found at the European level, for instance, in the 8th EU Framework Programme for Research and Innovation, which explicitly supports and facilitates civil society participation in science (e.g. Engage 2020 2014, Thomas 2015, Wehling 2012, Frickel 2010). This includes not only participation in the research process as such (e.g. in transdisciplinary sustainability research, see below), but also participation of citizens in

research agenda setting processes, in academic boards and committees or in project-based education programs.[1]

Approaches of "co-production" have been developed more systematically in the international field of sustainability science as part of its programmatic demand for problem orientation and stakeholder participation in research (Kates et al. 2001; Clark and Dickson 2003, 8059; Clark 2007; Miller 2012). In the field of transdisciplinary research, integrated methodologies and well-established sets of concrete methods have been developed for the participation of non-academic stakeholders and the integration of different forms of knowledge (Scholz and Tietje 2002, Jahn et al. 2012; Lang et al. 2012).

(3) Innovation

By producing knowledge and innovations, science can generate new options, increase the scope of societal action and open up previously unthought of solution spaces. The plea for a more explicit focus on solutions in the field of transdisciplinary sustainability science (Sarewitz et al. 2012; Wiek et al. 2012; Miller et al. 2014; Popa et al. 2015; Wiek and Lang 2016) is exactly about increasing the scope of action in dealing with unintended environmental and social side effects. This is not limited to technological innovations as the result of research in the natural sciences and engineering, but explicitly includes scientifically grounded social and institutional innovations (Howald/ Schwarz 2010).

(4) Balancing Power

Processes of societal transformation are inherently political, they involve power struggles and raise questions of fairness and social equity (for a discussion of the role of power in transitions, see Avelino 2011, Partzsch 2015). By increasing reflexivity, facilitating participation and the search for innovative solutions, science can help re-balance power in society. Power asymmetries benefitting established actors in politics, science and society can be shifted by strengthening niche actors through new forms of participation, by increasing the scope for action in relevant societal fields and by increasing reflexivity with regard to existing technologies and (political) strategies.

2 Conceptualizing Transformative Science

Through a combination of these functions, science can develop a significant transformative capacity in the age of reflexive modernity. We can therefore speak of *transformative science*, which is defined as:

a specific type of science that does not only observe and describe societal transformation processes, but rather initiates and catalyzes them. Transformative science aims to improve our understanding of transformation processes and to simultaneously increase societal capacity to reflect on them.

This definition – and ambition[2] – of the concept of transformative science has a number of implications with regard to (1) research and knowledge production, (2) education and teaching; and (3) institutional change of the science system. By including these three dimensions, the program of a transformative

[1] http://www.consider-project.eu/home

[2] The ambitious demands of a transformative science (Schneidewind and Singer-Brodowski 2014) have stimulated a controversial debate especially within the German science system (Strohschneider 2014; Grunwald 2015; Schneidewind 2015; von Wissel 2015). The concept of transformative science has been criticized for blurring the boundaries between science and society (Strohschneider) through instrumentalization by non-academic interest groups that are not democratically elected, a non-scientific focus on solutions ("solutionism") and an undue exaggeration of the role of science ("hypertrophy") (Strohschneider 2014). This debate clearly shows what the major obstacles for mainstreaming transformative science are. It seems questionable, whether the self-organizing capabilities of the science system will alone be effective in redirecting this autonomous sub-system towards greater societal responsibility (Glerup and Horst 2014).

science extends beyond approaches of transdisciplinary research that have been developed over the past 20 years (while building on their epistemological and methodological foundations).

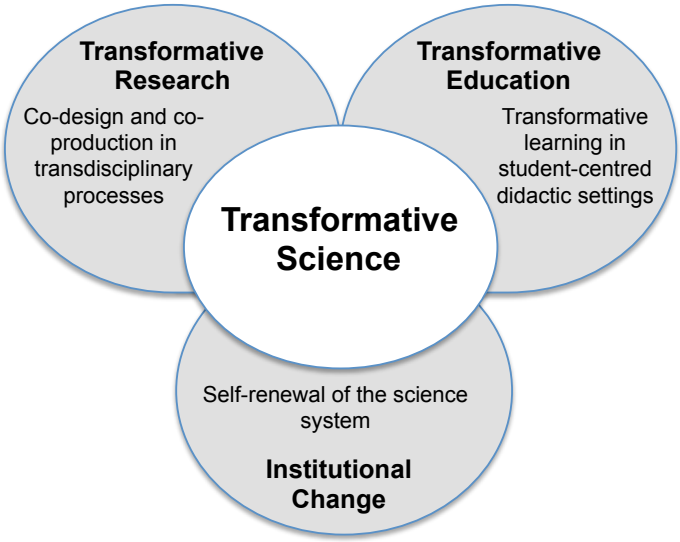

Figure 2: Three dimensions of a transformative science (Source: Own illustration).

A major difference is that the concept of transformative science shifts the focus beyond the societal impact of specific technologies or transdisciplinary projects and towards a more systematic understanding of the transformative impact of science in and on society. Transformative science engages in an active dialogue with societal stakeholders and accepts the challenge that comes with this by explicitly questioning and reflecting its own implicit assumptions. This presents a fundamentally new challenge of systemic change within the organizations responsible for the production of knowledge (Dedeuderwaerde 2013, König 2015).

Beyond the sphere of traditional scientific institutions, transformative science also takes a key role in establishing creative laboratories and room for experiments in a broader societal context. Transformative science thus integrates approaches of transformative research and transformative education to initiate change in key areas of activity of scientific institutions as well as a focus on institutional change in the science system as a central sub-system within modern societies (see Fig. 2). The following sections will focus on all three dimensions in detail.

2.1 Transformative Research – Co-Design and Co-Production in Transdisciplinary Processes

Transformative research is a new research approach. Its potential and limitations still need to be defined and methodological challenges have to be addressed. In the German-speaking countries Germany, Austria and Switzerland a broad conceptualization of transformative research has been developed over the last years, which offers relevant insights to the European and international debate about "Responsible Research and Innovation".

So, what does transformative research imply with regard to concepts and methods? As a first building block approaches of transdisciplinary research can be referred to (Jahn et al. 2012; Lang et al. 2012; Jahn and Keil 2015). While these approaches focus on the integration of different types of knowledge, transformative research emphasizes the role of scientific knowledge production as a form of societal

intervention that aims at catalyzing societal change processes. The German Advisory Council on Global Change describes this active intervention of science as follows:

'Transformative research supports transformation processes in practical terms through the development of solutions and technical and social innovations, including diffusion processes in economy and society, and opportunities for their acceleration, and demands, at least in part, systemic perspectives and inter- as well as transdisciplinary procedure methods, including stakeholder participation.' (WBGU 2011, 351)

Transformative research aims at paradigmatic change and adopts a normative position. It is oriented towards a more sustainable society and wants to contribute actively to the transformation processes needed to achieve this goal. Sustainable development is in this context understood as an extension of universal human rights and thus amounts to a human-oriented civilization project. Following such a normative orientation, transformative research can be positioned as part of the field of sustainability science, which is growing continuously since around the year 2000 (Kates et al. 2001; Clark and Dickson 2003; Clark 2007; Jerneck et al. 2011; Miller 2012; Brandt et al. 2013). Within the field of (transdisciplinary) sustainability science, different approaches can be distinguished (Popa et al. 2015, 49 et seq; Wiek and Lang 2016). Among these, transformative research can be characterized as an approach that focuses more explicitly on societal impact (rather than academic observation) and on societal deliberation processes between scientists and non-academic stakeholders (rather than integrating different types of knowledge). From an epistemological point of view, transformative research can be related to the tradition of pragmatism, where the strict separation of knowledge and experience disappears (Dewey 2000, 343-361).

A similar debate is currently taking place at the European level. The concept of "Responsible Research and Innovation" (RRI) in this context describes a research paradigm that focuses on anticipating the potential societal impact of research, on the development of co-design and co-production in research designs, and on facilitating innovation and sustainable development. Societal actors, including scientists, citizens, politicians and businesses, should collaborate in research and innovation processes, to better ensure that results meet the expectations, needs and values of society (Glerup and Horst 2014). The RRI concept assumes a partnership between science and society, which allows science to fulfill its tasks responsibly and legitimized by society (Guston et al. 2014). Similarly, transformative research also builds on the ideal of a cooperative relationship between science and society. In contrast to RRI, transformative research does not only explore options of radical change towards sustainability, it additionally contributes to processes of initiating, steering and increasing reflexivity in societal transformations.

A very different understanding, as compared to the European discourse, of transformative research has been adopted by the US National Science Foundation:

> *"Transformative research is research driven by ideas that stand a reasonable chance of radically changing our understanding of an important existing scientific concept or leading to the creation of a new paradigm or field of science. Such research also is characterized by its challenge to current understanding or its pathway to new frontiers." (NSF, 2007, p. 10).*

According to this definition, transformative research is about an inner-academic paradigm change (Kuhn 1962) and the emergence of new epistemic communities or "thought collectives" (Fleck 1980). Such a narrow conceptualization of transformative research is only to a very limited extent suitable for discussing the unintended side effects produced by the science system in an age of reflexive modernity.

From a methodological point of view, transformative research builds on the experimental turn in the social sciences (Morton and Williams 2010; Overdest et al. 2010) and makes use of a broad repertoire of research approaches, which focus on joint learning and experimenting of scientists and lay persons, such as transdisciplinary case studies (Scholz and Tietje 2002; Scholz et al. 2006; Stauffacher et al. 2006), participative action research (Greenwood and Levin 2007; Reason and Bradbury 2008, Wittmayer and Schäpke 2014), intervention research (Rothman and Thomas 1994, Fraser et al. 2009; Krainer and Lerchster 2012) or transition research (Schot and Geels 2008; Berkhout et al. 2010; van den Bosch and Rotmans 2008) (For an overview of the different research approaches, see Table 1).

Approach	Characteristics	Authors
Transdisciplinary case studies	Transdisciplinary case studies are well-established in sustainability science and are used to study real-world phenomena in context, especially where the boundaries between studied phenomenon and context cannot easily be drawn. Research questions are usually questions of "why" and "how" and data is generated through triangulation of methods. Since many sustainability problems are complex, characterized by uncertainty and involving many stakeholders, case studies can help integrate various types of relevant knowledge and facilitate the generation of socially robust knowledge.	Scholz and Tietje 2002; Scholz et al. 2006; Stauffacher et al. 2006, Kyburz-Graber 2016; Yin 2003; Stake 2005
Transdisciplinary research	Transdisciplinary research is reflexive, integrative, method-driven research with a focus on solving societal problems as well as scientific questions. Different types of scientific and non-academic knowledge are distinguished and methods are being developed for integrating these different types of knowledge.	Bergmann et al. 2010; Lang et al. 2012; Jahn et al. 2012; Defila and DiGiulio 1999
Action research	The tradition of action research goes back to the work of social-psychologist Kurt Lewin during the 1940s and has been applied in various disciplines (political science, urban and regional development studies, educational research, organization studies). Action research has emerged as a critique of the experimental social-psychological methods dominant at that time, which assumed scientists as experts, neutral and distant observers of lay persons as mere objects of study. Action research emphasizes cooperation and collaboration between scientists and lay persons as a way of generating socially relevant and applicable knowledge as well as new social relations and change in the field of study.	Greenwood and Lewin 2007, Reason and Bradbury 2008; Wittmayer and Schäpke 2014, Wals 1994
Intervention research	The aim of intervention research is to initiate – through doing research – individual reflection and learning, which eventually leads to collective reflexivity and enlightenment. Social learning processes in practice are the key focus of intervention research and learning is the result of permanent reflection in a dialogue with scientists, rather than through adopting scientific knowledge provided by scientists.	Fraser et al. 2009; Rothman and Thomas 1994; Krainer and Lerchster 2012; Heintel 2005; Lerchster 2012;
Transition research	Transition research is a new approach to sustainable development (SD) and is drawing on several inputs: complexity theory, integrated assessment, STS, innovation studies, history, governance studies, reflexive modernization, but is also developing its own core set of questions and theories. Major research efforts of a number of European research institutes in recent years have advanced knowledge of transitions to sustainability, particularly in the field of a broad understanding of how major, radical transformations unfold and what drives them.	Schot and Geels 2008; Berkhout et al. 2010; van den Bosch and Rotmans 2008

Table 1: Sources of transformative research in different fields (Source: Own illustration).

We argue that an integrated perspective on these research approaches under the umbrella concept of transformative science can foster a more comprehensive understanding and an improved contribution to sustainability transformations in practice. They share some basic characteristics: they recognize and integrate various types of knowledge, they take a critical stance towards conventional research paradigms and they strive for a new contract between science and society (science *in* and *with* society) (see also mode-2 science (Nowotny et al. 2001) and post-normal science (Funtowicz and Ravetz 1993). In essence, transformative research emerges as a result of innovation and modernization dynamics that produce knowledge deficits, uncertainty and risk (Krohn 2007).

2.1.1 Research in Real-World Labs

A current example of an "ideal-type" form of transformative research is the newly emerging concept of research in real-world labs (Schneidewind 2014; De Flander et al. 2014; Schäpke et al. 2015). This concept is still young and a broadly shared definition does not exist as of yet. According to our understanding, real-world labs provide "contexts for real-world experiments, which aim at an improved understanding of transformation processes and actively facilitate them" (Schneidewind 2014).

The key idea of studying and initiating change in real-world labs is to actually develop solutions, test and experiment with them (WBGU 2014; De Flander et al. 2014; Wagner and Grunwald 2015). They are carried out in and with society, rather than within the confines of scientific labs (Gross et al. 2005, p. 11). Real-world labs are built on a transdisciplinary process understanding of the involved scientific and non-scientific actors, methods facilitating collaboration and knowledge integration as well as suitable project designs. In short, they can be described as places of learning, which can have various types of impact: they create socially robust and socially acceptable solutions for actual problems, they serve as testing ground for new knowledge and solutions, and they can facilitate transferability of solutions to other contexts. The basic assumption is that experimenting and learning-by-doing is important not only to initiate change, but also to arrive at a better understanding of transformation processes per se. Fields of application and research questions can be as diverse as the concrete physical locations or boundaries of a real-world lab. They can be urban districts or even entire cities or regions, national parks or nature reservation areas, a university campus as well as an industrial sector or supply chain as well as a regional mobility system (MWK 2013). Similar to case studies, real-world laboratories are delineated by the specific research question or field of application and they focus on a specific place or concept, e.g. a region (Ceschin 2014), city (Evans and Karvonen 2014) or organization (Evans et al. 2015) that can serve as a boundary objects facilitating knowledge integration. Various kinds of actors can relate to these boundary objects and thus are enabled to relate the different kinds of knowledge they possess to each other in a collaborative way (Schneidewind and Scheck 2013, p. 240) , and eventually initiate joint real-world experiments (Groß et al. 2005).

Successful collaboration of scientists and non-academic partners in real-world labs depends on fulfilling certain quality criteria of transdisciplinary sustainability science in order to guarantee knowledge integration. An additional and decisive factor is a high degree of reflexivity and transparency. Without these, real-world labs will not enable mutual learning (Scholz 2000), but will rather instrumentalize the non-academic partners as "lab rats". An essential precondition for doing research in real-world labs is the ability and willingness of the involved scientists to critically reflect their own roles in the process. In that sense, we can describe transdisciplinary research in real-world labs as a type of "learning research process" within a social space (Schneidewind and Singer-Brodowski 2015, 17). This can amount to a rather radical break with a more traditional understanding of roles in science, where scientists are the experts and lay persons the research objects. Real-world labs thus can have an impact not only on their specific field of application and the local stakeholders, but also on the involved scientists.

Doing transformative research in real-world labs can help strengthen reflexivity and it dissolves the strict separation of knowledge and experience, turning it into a more pragmatic perspective on joint research, learning and change. There is thus also a very direct link between transformative research and transformative education. An integrated perspective on research, education and the institutional system in which they are embedded, is the core feature of the concept of transformative science.

2.2 Transformative Education and Teaching

Since transformative science aims at reflexive knowledge production that can initiate change in society, it cannot rely only on the realm of academic research. Knowledge-based learning, teaching and education in universities are another key element of a transformative science. Even in a very traditional sense, higher education can be understood as a transformative endeavor, because it enables students to develop new ways of thinking and to question and change behavioural patterns. Where learning processes in universities are connected with societal change processes, a space is being created for "transformative learning" at the individual and societal level. Students who will be future decision-makers learn to deal with societal challenges and uncertainties in a pro-active way. They should develop an understanding for "wicked" sustainability problems, learn about approaches for solving them and eventually become change agents for a more sustainable society in the future.

In the context of the discourse on higher education for sustainable development, a dynamic research and practice community has emerged, addressing this rather comprehensive idea of approaching higher education in a societal context (i.e. Jones et al. 2010; Adomssent et al. 2006; de Kraker et al. 2007; Adomssent et al. 2009, Barth et al. 2011, Barth et al. 2016). This research field has emerged around the "UN Decade of Education for Sustainable Development" (ESD) (2005-2014), which has been launched with the overall objective of integrating ESD in all fields of education worldwide. In the final report of this UN Decade it was found that over the ten years it lasted progress has been made internationally with regard to the institutionalization of ESD in universities. However, it was also found that many countries are lacking pro-active "leadership" for a more substantial change in universities (UNESCO 2014, p. 115 ff.). Since 2015, efforts of strengthening ESD internationally are continued in the form of a UN World Program of Action.

A central aim of ESD in higher education is the development of competencies of students in the context of concrete sustainability problems. Especially against the background of complexity and uncertainty, competencies are essential as "the cognitive abilities and skills, which the individuals have available or can learn, and enable them to solve specific problems, as well as the motivational, volitional and social dispositions and abilities to successfully and responsibly use the solutions of problems in variable situations" (Weinert 2001, p. 27 f.). Over the past years, various classifications of relevant sustainability competencies have been developed for the field of higher education (e.g. Barth et al. 2007, de Kraker et al. 2009, Segales et al. 2009, UNECE 2012). In an international review by Wiek et al. (2011), the various competence models have been integrated and *five key competencies* were identified, which are essential for fostering sustainability transformations: (1) systems thinking, (2) anticipatory competence, (3) normative competence, (4) strategic competence. These are based on (5) interpersonal competence, which is a precondition for joint action (ibid.). The research agenda for the following years will be to develop an understanding of different levels of competence and based on this a concept for systematically measuring and evaluating students' competencies (Wiek et al. 2016).

2.2.1 Transformative Learning for Sustainability

The competencies in the field ESD are a systematic description of the desired results of education and students' learning processes in the context of sustainability. However, they do not contain an

understanding of *how* these competencies can be developed and acquired by students. This is an open research question in the field of ESD and environmental education and there is a need for more research that puts students and their individual learning experiences in the focus of analyses (Rickinson 2001, 209f., auch Dillon 2003). Many educational programs primarily focus on influencing and changing attitudes and behaviour towards more sustainable lifestyles (Rickinson 2001, p. 207). These approaches are criticized, because they are in essence a form of instrumentalization of students for addressing societal challenges (Jickling 1992, Scott and Vare 2007). A more adequate approach would be to familiarize students with different concepts and enable them to decide for themselves what positions they can and want to represent and to develop (political) attitudes in suitable teaching and learning settings (ibid.).

Therefore, ESD in higher education aims not only at systemizing relevant competencies, it also wants to encourage and enable students to reflect on their actions as consumers, citizens and learning human beings, without overwhelming them through given assumptions, rigid frameworks and pre-defined sets of competencies. Much more importantly, the individual experiences of students should be in the focus and their ability to engage in controversial deliberation processes between (1) students themselves, (2) students and teachers, and (3) students and societal stakeholders in the context of sustainability. The concept of transformative education and teaching we are proposing here is a relevant theoretical contribution to this debate, because it focuses on learning processes in contexts characterized by complexity and uncertainty and aimed towards greater reflexivity with regard to individual behaviour. Such a perspective is increasingly adopted in the field of ESD in higher education (Sterling 2011; Pavlova 2013a/ 2013b; Elliot 2010; Moore 2003; Sipos et al. 2007).

The theory of transformative learning does not follow an additive understanding of learning, where students add new knowledge to existing knowledge, it rather builds on a concept where an increasing reflexivity is the starting point and a precondition: (1) for consciously acting individuals, (2) for being able to develop new interpretations of contexts and situations, (3) for embedding what has been learned in a stable repertoire of interpretations and actions (Mezirow 1997, S. 82). Core focuses of transformative learning are subjective attributions of meaning, i.e. the individual schemes and frames that shape the perception and interpretation of new experiences (ibid., p. 10). Since these subjective attribution of meaning offer orientation and structure in everyday life, it is very difficult to change them (Illeris 2013). Transformative learning processes are therefore often triggered by irritations within personal worldviews or even minor crises regarding one's perceptions of self and the world surrounding him or her (Mezirow 1997). Such an experience can lead to a reflection of established attributions of meaning and patterns of interpretation, which can in turn create openness for change. Such a process can be facilitated in significant ways through non-hierarchical discourse (Mezirow 1991) with other students and the possibility to reflect on changing perspectives together. Learning together, in the protected environment of a group, reflection of new perspectives, hidden meaning and dominant ideologies (Brookfield 2000) can be a starting point for emancipation and the development of new worldviews and self-perceptions. These transformative learning processes lead to increased reflexivity and a changing relationship (Sterling 2010) with the social and natural environment. Deep-structural change in the assumptions that shape thinking, feeling and acting can lead to greater awareness and better ways of dealing with issues such as global injustice and the exploitation of humans and nature (Morrell and O'Connor 2002). Increased reflexivity can thus be achieved through a transformative learning experience, much rather than through a process where students are being convinced by a teacher to adopt more critical perspectives. Such a focus on transformative learning experiences is an important addition to research on competencies in ESD and it contributes a student-centered perspective on the learning process itself.

The development of competencies as well as transformative learning experiences can be facilitated by activating forms of teaching in alternative didactive settings (Cotton and Winter 2010). These are characterized by an interplay of practical activities and theoretical reflection (Savery 2006, p. 12). Based on real-world problems (Brundiers and Wiek 2011) students work on sustainability problems in small, interdisciplinary teams. In these kinds of didactic settings, students are no longer the subjects of their education, rather, they become active stakeholders in small-scale transformation processes and the related learning experiences (Wiek and Kay 2015). Especially in the context of the "Shift from teaching to learning" as part of the Bologna process, these didactic forms of higher education gain impetus. An overview of specific didactic tools and formats will be given in the following.

2.2.2 Didactic Formats fostering the development of competencies and transformative learning

In principle, these didactic formats in ESD can be summarized under the concept of problem-based learning (Dobson and Tomkinson 2012; Brundiers and Wiek 2011; Bessant et al. 2013, Cörvers et al. 2016). A key difference is whether they can be characterized as research-oriented or project-oriented learning (Brundiers and Wiek 2013).

Research-oriented learning focuses on gaining a deeper understanding of a phenomenon and its context with the aim of producing knowledge with regard to a specific sustainability problem. Ideally, the process of knowledge generation is embedded in a transdisciplinary or transformative research design. Students are confronted with a complex sustainability problem and will then be supported by teachers in carrying out a small research project, including the development of a research question, selection of suitable methods, evaluating and presenting results. Transdisciplinary case studies (Scholz et al. 2006) are a typical format for doing these kinds of research projects. Teachers take on the role of facilitators that assist students with their practical expertise in the respective field as well as with their theoretical and methodological knowledge. According to Barrows (1996), research-oriented learning is characterized by six features:

1 | Learning is student-centered,
2 | Learning occurs in small student groups,
3 | Teachers are facilitators or guides
4 | Problems form the organizing focus and stimulus for learning.
5 | Problems are a vehicle for the development of (...) problem-solving skills and
6 | New information is acquired through self-didactic learning.

Project-oriented learning is also characterized by these features, but the focus is on solving in practice a specific sustainability problem in a concrete local context. It is thus also based on a real-world problem, but the project result, sometimes in the form of a concrete product, is decisive and a more clearly specified goal (Savery 2006, p. 1). The problem in question can emerge from a cooperation with civil society partners and learning in these contexts can be further specified as "service learning" (Barth et al. 2014). Here, students learn about the respective subject matter by working in nonprofit/civil society organizations and then reflect on it theoretically (Eyler and Giles 1999). Another example is the development of sustainability projects on campus by the students themselves: organizing events, preparing a sustainability report for the university, doing campaigns for concrete sustainability activities at the university, e.g. in the field of energy efficiency and saving energy or serving fair-trade coffee at the university canteen.

Project-oriented learning can thus contribute to actual improvements in the sustainability performance of universities and it can be an effective element in teaching. A precondition for developing competencies in project-oriented learning is the theoretical reflection of the practical experience.

Facilitating theoretical reflection is the task of the involved teachers as well as supporting and coaching the students in the project management process (Savery 2006, 15).

In essence, transdisciplinary or transformative learning in research-oriented learning approaches as well as the focus on developing concrete solutions in project-oriented learning formats offer students access to new types of knowledge: the locally embedded understandings and experiences of stakeholders (Alvarez and Rogers 2006, 178) as well as the manifold complexities of sustainability problems in practice. Students are encouraged to look at local sustainability problems from various perspectives, taking into account the discourses and practices of various stakeholder, and to develop a deeper understanding of the ambiguities, uncertainty and multidimensional nature of sustainability transformations (ibid. p. 182 f.). Research- and project-oriented learning can thus be seen as complementary in ESD (Brundiers and Wiek 2013, 1728).

Research- as well as project-oriented learning formats enable students to become more pro-active and engage in transformation processes. Self-organized learning (Knowles 1975, Candy 1991, Boekarts 1999) and the freedom to design their own projects can contribute to students' intrinsic motivation (Deci and Ryan 1985) and facilitate identification with their projects (Wheeler et al. 2010, p. 20). The experimental character of projects allows for making mistakes (within the protected space of the university) as an essential part in the process of learning.

Higher education that is based on principles of transformative learning can have three kinds of impact: (1) impact on students through facilitating ESD and enabling them to act as "pioneers of change" and responsible citizens of a global society; (2) impact on didactics that need to be changed in order to allow for an interplay of practical experience and theoretical reflection; (3) impact on society by embedding teaching and learning activities in the university's environment.

2.3 Institutional Change – Self-renewal of the Science System

For transformative research and transformative teaching and learning to spread more broadly, institutional change in the science system is required. Such an institutional dimension has been lacking in the debate about mode-2 science so far. However, a comprehensive concept of transformative science needs to include an institutional dimension[3]. Institutional change in that sense refers not only to the organizational structures of academia as a whole or individual scientific bodies, but also rule systems and paradigms embodied in academic cultures, the incentive structures and reputation systems and scientific quality criteria (for an overview of strategies for institutional reform towards a more transformative science system, see: Schneidewind 2010, Schneidewind/Singer-Brodowski 2014, S. Schneidewind et al. 2016a).

In the following, institutional change at three levels will be discussed: (1) a fundamental mindshift in the self-conception and attitude of scientists as individuals; (2) a regime shift towards greater participation of civil society, scientific quality criteria and quality assurance systems for a transformative science and organizational change at the level of universities and non-academic research bodies; (3) instruments and measures for an institutional reform program at the political level.

2.3.1 Mindshift

Transdisciplinary research and transformative teaching and education as well as the overall concept of a transformative science are all based on a specific perspective on the role of knowledge and scientists in and for society. Science is not understood as being isolated from society, taking place in a sub-system

[3] Schneidewind/Singer-Brodowski describe transformative science as mode-3 science, i.e. adding an institutional dimension to the debate about a mode-2 science.

following its own specific rules, but rather as an embedded process, generating knowledge with and for a changing society – in a "transdisciplinary process" (Scholz 2011). Such a fundamental approach challenges self-conceptions and traditional roles of scientists. The relationship between scientists and society has to be redefined where they take real-world problems as the starting point for research, where research questions are framed together with societal stakeholders and where different types of disciplinary and non-academic knowledge need to be integrated. This is in stark contrast to the ideal of the lonely academic searching for the truth in isolation from societal turmoil. Defensive reactions and critique of transformative science approaches can thus often be explained by a clash of basic conceptions of science and the role of scientists. At its core are conflicting self-conceptions of scientists that transcend the cognitive-rational level.

It is therefore crucial to emphasize that the concept of transformative science does not aim at the abolition of disciplinary and basic research, which require a more traditional research approach and scientific practice, including the related self-conceptions of scientists. However, in an age of reflexive modernity, there is an additional need for a more transformative science and ways have to be found for enabling the co-existence of different scientific cultures in the science system. Similar dynamics have led to changes in the science system before, e.g. in the case of the emerging engineering sciences (see Grunwald 2015). A mindshift is needed that embraces these pluralizing dynamics (in a reflexive and critical way), in order to open up the space for concrete institutional change.

2.3.2 Regime Shift

Three key areas where institutional change is needed in order to enable a more transformative science will be discussed in the following, in order to illustrate the fundamental challenges involved in a broader institutional reform program: (1) greater participation of civil society in science, (2) rethinking scientific quality criteria and quality assurance systems, and (3) organizational change at the level of universities and non-academic research bodies.

Participation

Involving societal stakeholders in the co-design of research questions and designs and in the co-production of knowledge is a key challenge for the established institutional structure of the science system and is therefore discussed controversially. While methods for stakeholder involvement in transdisciplinary processes and cases studies have been developed, there are no established mechanisms for civil society participation in science at a level beyond individual research projects. This would require a more systematic participation of civil society organizations in the design of publicly funded research programs, capacity building through mediating institutions, such as Science Shops, for instance, and further developing citizen science as a specific form of co-production of scientific knowledge (Irwin 1995; Roy et al. 2012, Haklay 2013).

Scientific quality criteria and quality assurance systems

Scientific quality criteria and quality control mechanisms are of key importance for building a reputation in the science system. Apart from traditional academic quality criteria, there is a need for alternative quality criteria able to evaluate transformative science approaches. Their co-existence with traditional science depends on broadly accepted criteria and measures of distinguishing "good" and "bad" transformative science – in co-existence with the elaborated scientific quality assurance systems already in place.

In the field of transdisciplinary research, approaches of quality assurance have been developed (e.g. Jahn/Keil 2015.). However, a key aspect remains somewhat neglected: measuring societal impact. Since transformative science aims at fostering sustainability transformations in practice, a better

understanding is needed of the societal impact and suitable approaches for evaluating sustainability impacts in society.

In the field of transformative science, i.e. science that proactively fosters transformative processes (WBGU 2011, p. 23), the mechanisms through which science has a transformative impact are varied and complex. Impact is produced through different kinds of levers – e.g. technologies, specific project results, policy recommendations, coining terms and developing new frames and narratives, individual scientists – and they differ depending on the specific field of application and arena. An analytically clear and linear reconstruction of causal impact chains (e.g. along the lines of input – output – outcome) that goes beyond generic heuristics is hardly feasible (e.g. Wiek et al., 2014). Existing approaches of measuring impact based on formative criteria (e.g. Bergmann et al. 2005; Jahn and Keil 2015) of process conditions for successful transformative research also remain limited. A better understanding is needed of what the varying types of impact and their underlying mechanisms are, in order to facilitate the learning processes in the field of transformative science (Schneidewind and Singer-Brodowski, 2014).

A useful orientation is offered by the British "Research Excellence Framework", where the impact of research is evaluated based on best practice case studies. To generalize results beyond the level of individual cases, the analytical framework of Spappen and van Drooge (2011), which is based on the concept of "productive interactions", can be a useful addition. According to this framework, interactions between science and society (i.e. scientists and stakeholders) are a key factor for producing impact. Building on this framework and a case study analysis, typical patterns can be identified for the production of societal impact. This approach allows for a systematization of the broad variety of impact mechanisms into a comprehensive set of typical patterns of transformative research that has a societal impact. Research on "pattern language" (e.g. Alexander et al. 1977) offers interesting perspectives on conceptualizing patterns in the emergence of societal impact. Alexander et al. (1977, p. 10) find that „each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution of that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice". The focus of such an approach is on the relationship between the parts of a system and how their interplay contributes to the functioning of the system as a whole (Stark and Schümmer, 2014, 25).

Organisational change facilitating transdisciplinarity and transformative science

Finally, institutional change for transformative science is needed within the organizations of the science system, i.e. universities and other research institutions. Their organizational structures reflect the traditional academic and disciplinary modes of knowledge production. Interdisciplinary centers do exist, but they often build bridges between disciplines that are closely related, e.g. in the field of natural sciences and engineering, in medical research, or in the social sciences. In the following an overview is given of some key institutional reforms and initiatives that together can contribute to a relevant degree of capacity building for a transformative science:

- Establishing transdisciplinary centers for research and education that cross disciplinary boundaries between the natural and the social sciences, and involve societal stakeholders. Some examples of this type of institutions already exist, e.g. the Stockholm Resilience Center or the Dutch Research Institute for Transitions (DRIFT).
- Establishing university faculties with a transdisciplinary orientation (e.g. the Leuphana University Lüneburg in Germany or the School for Sustainability at Arizona State University). They can create the basis for transdisciplinary study and dissertation programs.

- Establishing infrastructures for transdisciplinary knowledge integration in research and education: (urban) real-world labs designed for longer periods of time can function as a more permanent transdisciplinary setting and process (WBGU 2016).
- Establishing institutes or centers that focus on the development of methods for a transformative science. It has been shown in this paper that there is a need to further develop suitable methods in transformative research (and education) and similar to disciplinary science, these should be developed and taught in specialized centers. These can also become initiators for publishing scientific journals with a transdisciplinary focus.

These examples provide a brief overview of concrete measures that could be part of a more comprehensive institutional reform program facilitating transformative science.

2.3.3 Getting Started

A key question is how such an institutional change agenda could be implemented in current science systems characterized by path dependencies and inertia. Some empirical evidence of promising approaches does exist. In the following, three examples will be presented:

- **Funding programs** can have an important signaling function for the science system as a whole and they can create the experimental space for developing transformative science approaches. Important funding bodies in this respect can be foundations (see the example of the Stockholm Resilience Center), national funding bodies (e.g. the Social-Ecological Research program of the German Federal Ministry of Education and Research, or as an example in the field of transformative education and learning, the Austrian Ministry of Economics' "Sparkling Science" program), or public funding bodies below the national level (e.g. the real-world lab program of the German federal state Baden-Württemberg[4]. It is important that these funding programs do not only work on a project-basis, but also create incentives for long-term capacity building, e.g. by establishing centers that receive initial funding or by establishing tenure-track professorships.
- **Pioneering institutions.** Institutional change in the science system depends on a critical mass of national and international pioneering institutions that embrace principles of transformative science as part of their strategic mission. This is important for long-term capacity building based on a systematic development of methods, publishing journals, developing quality criteria and quality control systems, and by creating career opportunities for scientists in the field of transdisciplinary and transformative science. Today, only a few isolated examples of pioneering institutions already exist, such as Arizona State University in the US or the Leuphana University in Germany as well as networks of non-university sustainability research institutes, e.g. the Ecornet in Germany (http://www.ecornet.eu). Further incentives are needed, such as the excellence programs in various national science systems, in order to facilitate a more varied and horizontal differentiation within the science system.
- **Participation of civil society.** An important catalyst for institutional change in the science system are civil society organizations, especially where they openly state their demands with regard to the role of science in the political arena and directly addressing scientific institutions. This can create the political momentum needed for substantial reforms. With regard to commercialization and industry interests there have been vast changes within the science system over the past decades. Similar mechanisms should be used in the context of societal interests and to establish a new contract between science and society.

[4] https://mwk.baden-wuerttemberg.de/de/forschung/forschungspolitik/wissenschaft-fuer-nachhaltigkeit/reallabore/

3 Conclusions: Transformative Science as a paradigmatic, institutional and methodological reform program

This paper has outlined the program and the key elements of a "transformative science" and the related need for institutional change. The concept of transformative science extends beyond established discourses of mode-2 science and approaches of transdisciplinary research, because it addresses issues related to transformative research as well as transformative education and learning, and it focuses on the institutional dimension of science system change. Transformative science is a self-reflexive program for further developing science, by critically questioning and reflecting on its own role in societal transformation processes.

The following aspects are crucial for further developing the program of transformative science:

- The debate about transformative science needs to be internationalized, building on and extending far beyond individual European and US hubs. A suitable framework for this could be the global Future Earth program (http://www.futureearth.org).
- Challenges addressed in this paper, e.g. development of methods and quality criteria, the need for pioneering institutions and funding programs, need to be focused on and developed further.
- The basic concept of a transformative science needs to be translated and adapted in different fields of application, e.g. as a transformative economics and business studies (see Schneidewind et al. 2016b), transformative chemistry or transformative computer sciences.

Building a new contract between science and society remains a challenge and a comprehensive reform project for the science system in the 21st century.

4 References

Adomßent, M.; Beringer, A.; Barth, M. (Hrsg.) (2009): World in Transition: Sustainability Perspectives for Higher Education. Verlag für akademische Schriften: Frankfurt a.M.

Adomßent, M.; Godemann, J.; Leicht, A.; Busch, A. (Hrsg.) (2006): Higher Education for Sustainability: New Challenges from a Global Perspective. Verlag für akademische Schriften: Frankfurt a. M.

Alexander, C./Ishikawa, S./Silverstein, M./Jacobson, M./ Fiksdahl-King, I./Angel, S. (1977): A Pattern Language. Towns, Buildings, Construction. New York: Oxford University Press.

Alvarez, Amaya; Rogers, Judy (2006): Going "out there": learning about sustainability in place. In: International Journal of Sustainability in Higher Education 7 (2), S. 176-188. DOI: 10.1108/14676370610655940

Avelino, F. (2011). *Power in Transition: Empowering Discourses on Sustainability Transitions* (Dissertation). Rotterdam: Erasmus University Rotterdam, Faculty of Social Sciences (FSS).

Barrows, Howard S. (1996): Problem-based learning in medicine and beyond. In: Wilkerson, LuAnn; Gijselaers, Wim H. (Hrsg.): Bringing Problem-Based Learning to Higher Education. Jossey-Bass: San-Francisco, S. 3-12.

Barth, Matthias; Adomßent, Maik; Fischer, Daniel; Richter, Sonja; Rieckmann, Marco (2014): Learning to change universities from within: a service-learning perspective on promoting sustainable consumption in higher education. In: Journal of Cleaner Production 62, S.72-81. DOI: 10.1016/j.jclepro.2013.04.006

Barth, M.; Michelsen, G.; Rieckmann, M.; Thomas, I. (Hrsg.) (2016): Routledge Handbook of Higher Education for Sustainable Development. Routledge: Abingdon/ New York

Barth, Matthias; Godemann, Jasmin; Rieckmann, Marco; Stoltenberg, Ute (2007): Developing key competencies for sustainable development in higher education. In: International Journal of Sustainability in Higher Education 8 (4), S. 416-430. DOI: 10.1108/14676370710823582

Barth, M.; Rieckmann, M.; Sanusi, Z. A. (Hrsg.) (2011): Higher Education for Sustainable Development: Looking Back an Moving Forward Verlag für akademische Schriften: Frankfurt a.M.

Beck, U. (1986): Risikogesellschaft. Auf dem Weg in eine andere Moderne. Suhrkamp, Frankfurt a.M. 1986. (19. Aufl. 2007).

Berkhout F. et al. (2010). Sustainability experiments in Asia: innovations shaping alternative development pathways? Environmental Science & Policy 13, 261-271.

Bessant, Sophie; Bailey, Patrick; Robinson, Zoe; Tomkinson, Bland C.; Tomkinson, Rosemary; Ormerod, Mark R.; Boast, Rob (2013): Problem-Based Learning: a case study of sustainability Education. Download unter: www.keele.ac.uk/media/keeleuniversity/group/hybridpbl/PBL_ESD_Case Study_Bessant, et al. 2013.pdf (letzter Zugriff: 11.03.2015)

Boekarts, M., 1999. 'Self-regulated Learning: Where we are Today', *International Journal of Educational Research,* 31(6), 445–57.

Brandt, P.; Ernst, A.; Gralla, F.; Luederitz, C.; Lang, D. J.; Newig, J.; Reinert, F.; Abson, D. J.; von Wehrden, H. (2013): A review of transdisciplinary research in sustainability science, In: Ecological Economics, 92: 1-15.

Brookfield, Stephen D. (2000): Transformative learning as ideology critique. In: Mezirow, Jack (Hrsg.): Learning as transformation: Critical perspectives on a theory in progress. Jossey-Bass: San Francisco, S. 125-148.

Brundiers, Katja; Wiek, Arnim (2011): Educating Students in Real-world Sustainability Research: Vision and Im- plementation. In: Innovative Higher Education 36 (2), S. 107-124. DOI: 10.1007/s10755-010-9161-9

Brundiers, Katja; Wiek, Arnim (2013): Do we teach what we preach? An International Comparison of Problem- and Project-based Learning Courses in Sustainability. In: Sustainability 5 (4), S. 1725-1746. DOI: 10.3390/su5041725

Candy, P.C., 1991. Self-Direction for Lifelong Learning. A Comprehensive Guide to Theory and Practice. San Francisco, CA: Jossey-Bass.

Ceschin, F., 2014. How the Design of Socio-technical Experiments Can Enable Radical Changes for Sustainability. Int. J. Des. 8, 1–21.

Clark, W. C. (2007): Sustainability Science: A room of ist own. In: Proceedings of the National Academy of Sciences of the United States of America, Vol. 104 (6), S. 1737-1738, http://doi:10.1073/pnas.0611291104

Clark, W. C.; Dickson, N. M. (2003): Sustainability science: The emerging research programm. In: Proceedings of the National Academy of Sciences of the United States of America. Vol. 100 (14), S. 8059-8061, http://dx.doi.org/10.1073/pnas.1231333100

Cotton, D./ Winter, J. (2010), "It's not just bits of paper and light bulbs: a review of sustainability pedagogies and their potential for use in higher education", in Jones, P./ Selby, D./ Sterling, S. (Ed.), *Sustainability education: Perspectives and practice across higher education*, Earthscan, London, pp. 39- 54.

Cörvers, R.; Wiek, A.; de Kraker, J.; Lang, D. J.; Martens, P. (2016): Problem-Based and Project-Based Learning for Sustainable Development. Heinrichs, H.; Martens, P.; Michelsen, G.; Wiek, A. (Hrsg.): Sustainability Science: An Introduction. Springer: Dordrecht u.a., S. 349-358

Crutzen, Paul (2002): The „anthropocene". In: Journal de Physique IV France 12 (10), S. 1-5. DOI: 10.1051/jp4:20020447

De Flander, Katleen; Hahne, Ulf; Kegler, Harald; Lang, Daniel; Lucas, Rainer; Schneidewind, Uwe; Simon, Karl-Heinz; Singer-Brodowski, Mandy; Wanner, Matthias; Wiek, Arnim (2014): Resilienz und Reallabore als Schlüsselkonzepte urbaner Transformationsforschung – Zwölf Thesen. In: GAIA Jg. 23 (3), S. 284 – 286

De Kraker, J.; Lansu, A.; van Dam-Mieras, R. (Hrsg.) (2007): Crossing Boundaries: Innovative Learning for Sustainable Development in Higher Education. Verlag für akademische Schriften: Frankfurt a. M.

De Kraker, J., Lansu, A. and van dam Mieras, R., 2009. 'Competences and competence- based learning for sustainable development', in de Kraker, J., Lansu, A. and van dam Mieras, R. (eds), *Crossing Boundaries. Innovative Learning for Sustainable Development*. Frankfurt a.M.: VAS, 103–14.

Deci, E.L. and Ryan, R.M., 1985. Intrinsic Motivation and Self-determination in Human Behavior. New York: Plenum.

Dedeurwaerdere, T. (2013): Transdisciplinary sustainability science at higher education institutions: Science policy tools for incremental change. In: Sustainability, Vol. 5, 3783-3801.

Defila R., Di Giulio A. (1999): Evaluating Transdisciplinary Research – Evaluation Criteria for Inter and Transdisciplinary Research. In: Panorama. Special Issue 1/99.

Dewey, John (2000): Demokratie und Erziehung. Eine Einleitung in die philosophische Pädagogik. Herausgegeben und mit einem Nachwort von Jürgen Oelkers (englischsprachige Originalausgabe 1916). Beltz: Weinheim/ Basel.

Dillon, Justin (2003): On Learners and Learning in Environmental Education: Missing theories, ignored communities. In: Environmental Education Research 9 (2), S. 215-226. DOI: 10.1080/13504620303480.

Dobson, H. E.; Tomkinson, C.B. (2012): Creating sustainable development change agents through problem-ba- sed learning: Designing appropriate student PBL projects. In: International Journal of Sustainability in Higher Education 13 (3), S. 263-278. DOI: 10.1108/14676371211242571.

Elliott, Jennifer (2010): Insights to Transformative Learning through Education for Sustainable Development. In: Learning and Teaching in Higher Education 5, 96-113. Available at: http://insight.glos.ac.uk/tli/resources/lathe/Documents/issue 5/articles/Lathe_5_J Elliott.pdf

Engage 2020 (2014): Tools and instruments for a better societal engagement in "Horizon 2020". Deliverable 3.1 - report on current praxis of policies and activities supporting societal engagement in research and innovation. Brüssel. (Download unter: http://engage2020.eu/media/D3.1-Current-Praxis-of-Policies-and-Activities.pdf)

Evans, J., Karvonen, A., 2014. “Give Me a Laboratory and I Will Lower Your Carbon Footprint!” - Urban Laboratories and the Governance of Low-Carbon Futures. Int. J. Urban Reg. Res. 38, 413–430. doi:10.1111/1468-2427.12077

Evans J, Jones R, Karvonen A, Millard L, Wendler J: Living labs and co-production: university campuses as platforms for sustainability science. In: Current Opinion in Environmental Sustainability, Vol. 16 (Oktober 2015), S. 105-111. doi:10.1016/j.cosust.2015.08.011

Fleck, Ludwig (1980): Die Entdeckung einer wissenschaftlichen Tatsache. Einführung in die Lehre vom Denkstil und Denkkollektiv. Mit einer Einleitung hg. v. Lothar Schäfer/Thomas Schnelle, Frankfurt am Main 1980 (Originalausgabe Basel 1935).

Fraser, Mark, W.; Richman, Jack, M.; Galinsky, Maeda, J.; Day, Steven, (2009): Intervention Research. Developing Social Programs. Oxford University Press: Oxford

Frickel, Scott et al. (2010), Undone science: Charting social movement and civil society challenges to research agenda setting. In: Science, Technology & Human Values, Vol. 35, S. 444– 473.

Funtowicz, S., Ravetz, J. (1993): Science for the post-normal age. In: Futures Vol. 25, S. 739–755.

Gibbons, M. (1999): Science’s new social contract with society, Nature 402 (Suppl.) (1999)

Giddens, A. (1984): The Constitution of Society. Outline of a Theory of Structuration. Polity Press, Cambridge 1984.

Giddens, A. (1996): Konsequenzen der Moderne. Suhrkamp, Frankfurt a.M. 1996. (Neuauflage 2008).

Glerup, C.; Horst, M. (2014): Mapping ‘social responsibility’ in science, Journal of Responsible Innovation, 1:1, 31-50, DOI: 10.1080/23299460.2014.882077

Greenwood DJ, Levin M (2007) Introduction to Action Research. Social Research for Social Change, 2nd edn. Sage, Thousand Oaks

Groß, M.; Hoffmann-Riem, H.; Krohn, W. (2005): Realexperimente. Ökologische Gestaltungsprozesse in der Wissensgesellschaft. Bielefeld: Transcript.

Grunwald, A. (2008): Technik und Politikberatung. Suhrkamp, Frankfurt a.M. 2008.

Grunwald, A. (2013), Future Earth: Neue Dynamik in der globalen Nachhaltigkeitsforschung. In: GAIA, Vol. 22 No. 3, S.145.

Grunwald, A. (2015): Transformative Wissenschaft – eine neue Ordnung im Wissenschaftsbetrieb? In: GAIA Vol. 24 (1), S. 17–20.

Guston, D. H.; Fisher, E.; Grunwald, A.; Owen, R.; Swierstra, T.; van der Burg, S. (2014): Responsible innovation: motivations for a new journal, Journal of Responsible Innovation, 1:1, 1-8, DOI: 10.1080/23299460.2014.885175

Haklay, M. (2013): Citizen Science and Volunteered Geo- graphic Information: Overview and Typology of Participation. in: D. Sui/S. Elwood/M. Goodchild (Hrsg.): Crowdsourcing Geographic Knowledge. Dordrecht: Springer, S. 105–122.

Heintel, P. (2005): Zur Grundaxiomatik der Interventionsforschung. In: Heintel,P /Krainer, L./Paul-Horn, I./Ukowitz, M. (Hrg.): WBI Klagenfurter Beiträge zur Interventionsforschung, Band 1. Klagenfurt: Alpen-Adria-Universität Klagenfurt.

Howaldt, J./Schwarz, M. (2010): „Soziale Innovation“ im Fokus. Skizze eines gesellschaftstheoretisch inspirierten Forschungskonzepts. Bielefeld: Transcript Verlag.

Illeris, Knud (2013): Transformative learning and identity. Routledge: Abingdon, Oxon.

Irwin, A. (1995): Citizen Science. A Study of People, Expertise and Sustainable Development. London/ New York: Routledge.

Jahn, T., Bergmann, M., Keil, F. (2012): Transdisciplinarity – between Mainstreaming and marginalisation. In: Ecological Economics (79), S. 1-10, doi:10.1016/j.ecolecon.2012.04.017

Jahn, T.; Keil, F. (2015): An actor-specific guideline for quality assurance in transdisciplinary research. In: Futures. Volume 65, January 2015, Pages 195–208. doi:10.1016/j.futures.2014.10.015

Jerneck, A.; Olsson, L.; Ness, B.; Anderberg, S.; Baier, M.; Clark, E.; Hickler, T.; Hornborg, A.; Kronsell, A.; Lövbrand, E.; Persson, J. (2011): Structuring sustainability science. In: Sustainability Science, 6: S. 69-82 http://dx.doi.org/10.1007/s11625-010-0117-x

Jickling, Bob (1992): Why I don’t want my children to be educated for sustainable development. In: Journal of Environmental Education, 23 (4), S. 5-8. DOI: 10.1080/00958964.1992.9942801

Jones, Paula; Selby, David; Sterling, Stephen (2010) (eds.): Sustainability Education. Perspectives and Practices across Higher Education. Earthscan: London

Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C., Lowe, I., McCarthy, J. J., Schellnhuber, H.-J., Bolin, B., Dickson, N. M., Faucheuz, S., Gallopin, G. C., Gruebler, A., Huntley, B., Jäger, J., Jodha, N. S., Kasperson, R. E., Mabogunje, A., Matson, P.; Mooney, H., Moore, B., O’Riordan, T. & Svedin, U. (2001): Sustainability Science. In: Science 292, S. 641-642

Knowles, M 1975, *Self-directed learning. A Guide for learners and teachers*, Englewood Cliffs, New York.

König, A. (2015): Changing requisites to universities in the 21st century: organizing for transformative sustainability science for systemic change. In: Current Opinion in Environmental Sustainability. 16, 105-111.

Krainer, L.; Lerchster, R.E. (2012a) (Hrsg.): Interventionsforschung. Band 1. Paradigmen, Methoden, Reflexionen. Springer VS: Wiesbaden.

Krohn, Wolfgang (2007): Realexperimente – Die Modernisierung der 'offenen Gesellschaft' durch experimentelle Forschung. In: *Erwägen-Wissen-Ethik (EWE)*, Jg. 18, Heft 3, 343-356. Kritiken: 357-426. Replik des Autors: 427-442.

Kuhn, Thomas S. (1962) *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press).

Kyburz-Graber, Regula (2016): Case Study Research on Higher Education for Sustainable Development. Epistemological foundation and quality challenges. In: Barth, Matthias; Michelsen, Gerd; Rieckmann, Marco; Thomas, Ian (Hrsg.): Routledge Handbook of Higher Education for Sustainable Development. Routledge: Abingdon/ New York, S. 126-141

Lang, D. J., Wiek, A., Bermann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., Christopher T. J. (2012): Transdisciplinary research in sustainability science: practice, principles, and challenges. In: Sustainability Science, Vol. 7 (1), S. 25–43 http://dx.DOI10.1007/s11625-011-0149-x

Lerchster, R. (2012): Zentrale Grundannahmen der Interventionsforschung. In: Krainer, L.; Lerchster, R.E. (2012): Interventionsforschung. Band 1. Paradigmen, Methoden, Reflexionen. Springer VS: Wiesbaden. S. 23-74

Levin, Kelly; Cashore, Benjamin; Bernstein, Steven; Auld, Graeme (2012): Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change. In: Policy Science (2012) 45:123–152 DOI 10.1007/s11077-012-9151-0

Mauser, W./ Klepper, G./ Rice, M. et al. (2013), Transdisciplinary global change research: The co-creation of knowledge for sustainability. In: Current Opinion in Environmental Sustainability, Vol. 5, S. 420–431.

Mezirow, J. (1991): Transformative dimensions in adult learning. Jossey-Bass: San Francisco.

Mezirow, J. (1997): Transformative Erwachsenenbildung. Schneider Verlag Hohengehren: Baltmannsweiler.

Miller, (2012): Constructing sustainability science: emerging perspectives and research trajectories. In: Sustainability Science, Volume 8, Issue 2 , pp 279-293, DOI10.1007/s11625-012-0180-6

Miller, T. R., A. D. Wiek, D. Sarewitz, L. Olsson, D. Kriebel, Loorbach, D. (2014): The future of sustainability science: A solutions-oriented agenda. In: Sustainability Science Vol 9(2), S. 239-246. http://dx.doi:10.1007/s11625-013-0224-6

Minsch, J. u.a. (1998): Institutionelle Reformen für eine Politik der Nachhaltigkeit. Springer, Berlin 1998.

Moore, Janet (2003): Is Higher Education Ready for Transformative Learning? A Question Explored in the Study of Sustainability. In: Journal of Tranformative Education 3 (1), S. 76–91. DOI: 10.1177/1541344604270862

Morrell, Amish; O'Connor, Mary Ann (2002): Introduction. In: O'Sullivan, Edmund; Morrell, Amish; O Connor, Mary Ann (Hrsg): Expanding the Boundaries of Transformative Learning. Palgrave Macmillan: New York.

Morton, R. B.; Williams, K. C. (2010): Experimental Political Science and the Study of Causality: From Nature to the Lab. Cambridge: Cambridge University Press

MWK (Ministerium für Wissenschaft, Forschung und Kunst) Baden-Württemberg (2013): Wissenschaft für Nachhaltigkeit. Herausforderung und Chance für das baden-württembergische Wissenschaftssystem. Stuttgart: MWK.

National Science Foundation (NSF) (2007): Enhancing Support of Transformative Research at the National Science Foundation. National Science Foundation. http://nsf.gov/pubs/2007/nsb0732/nsb0732.pdf

Nowotny, H. (2003) Democratising expertise and socially robust knowledge, Science and Public Policy 30 (2003), S. 151–156

Nowotny, H., Scott, P., Gibbons, M. (2001): Re-Thinking Science. Knowledge in the Public in an Age of Uncertainty. Cambridge

Overdevest, C.; Bleicher, A.; Groß, M. (2010): The Experimental Turn in Environmental Sociology: Pragmatism and New Forms of Governance, in Groß, M./Hein- richs, H. (eds): Environmental Sociology: European Perspectives and Interdisciplinary Challenges (pp. 279-294). Heidelberg: Springer.

Partzsch, L. 2015. Kein Wandel ohne Macht – Nachhaltigkeitsforschung braucht ein mehrdimensionales Machtverständnis. *GAIA* 24/1: 48-56.

Pavlova, Margarita (2013a): Towards using transformative education as a benchmark for clarifying differences and similarities between Environmental Education and Education for Sustainable Development. In: Environmental Education Research 19 (5), 656-672. DOI: 10.1080/13504622.2012.736476

Pavlova, Margarita (2013b): Education for Sustainable Development and the Transformation of Self. How the World Can Become a Better Place to Live for All. In: Middleton, Howardt E.; Baartman, Liesbeth K.J. (Hrsg.): Transfer, Transitions and Transformations of Learning. Sense Publishers: Rotterdam, S. 123-132.

Popa, F.; Guillermin, M.; Dedeurwaerdere, T. (2015): A pragmatist approach to transdisciplinarity in sustainability research: From complex systems theory to reflexive science. In: Futures 65, 45–56

Reason P, Bradbury H (2008) (eds.): Handbook of action research: Participative inquiry and practice. Sage, London

Reid, W. V., Chen, D., Goldfarb, L., Hackmann, H., Lee, Y. T., Mokhele, K., Ostrom, E., et al. (2010) Earth system science for global sustainability: Grand challenges. In: Science, Vol. 330, S. 916-917.

Rickinson, M (2001), 'Learners and learning in environmental education: A critical review of the Evidence', *Environment Education Research*, vol. 7, no. 3, pp. 207-320.

Rip, Arie (2011): Science Institutions and Grand Challenges of Society: A Scenario. In Asian Research Policy 2, 1-9

Rockström, J. u.a. (2009): A safe operating space for humanity. In: Nature, Bd. 461, S. 461-472.

Rothman, Jack; Thomas, Edwin J. (Ed.) (1994): Intervention Research: Design and development for human services. Haworth Press: New York.

Roy, H.E./Pocock, M./Preston, C.M./Roy, D.B et al. (2012): Understanding Citizen Science and Environmental Monitoring. Final Report on behalf of UK Environmental Observation Framework.

Sarewitz, D.; Kriebel, D.; Clapp, R.;, Crumbley, C.; Hoppin, P.; Jacobs, M.; Tickner, J. (2012): The sustainable solutions agenda. New Solutions 22(2): S. 139–151

Savery, JR (2006), 'Overview of Problem-based Learning: Definitions and Distinctions', *Interdisciplinary Journal of Problem-based Learning*, vol. 1, no. 1, pp. 9-20.

Schäpke, N.; Singer-Brodowski, M.; Stelzer, F.; Bergmann, M.; Lang, D. J. (2015): Creating Space for Change: Real-world Laboratories for Sustainability Transformations. The Case of Baden-Württemberg. In: GAIA 24/4, S. 281– 283

Schneidewind Uwe (2010): Ein institutionelles Reformprogramm zur Förderung transdisziplinärer Nachhaltigkeitsforschung. In: GAIA. 19 (2), S. 122-128

Schneidewind, U. (2014): Urbane Reallabore – ein Blick in die aktuelle Forschungs werkstatt. pnd online 3.

Schneidewind, U. (2015): Transformative Wissenschaft – Motor für gute Wissenschaft und lebendige Demokratie. Reaktion auf A. Grunwald. 2015. Transformative Wissenschaft – eine neue Ordnung im Wissenschaftsbetrieb? GAIA 24 (1): 17 – 20. In: GAIA Vol. 24 (2), S. 88-91

Schneidewind, U., Scheck, H. (2013): Die Stadt als „Reallabor" für System - innovationen. In: Rückert-John, J. (Hrsg.): Soziale Innovation und Nachhaltigkeit: Perspektiven sozialen Wandels. Wiesbaden: VS Verlag für Sozialwissenschaften. 229–248.

Schneidewind, Uwe; Singer-Brodowski, Mandy (2014): Transformative Wissenschaft: Klimawandel im deutschen Wissenschafts- und Hochschulsystem. Metropolis: Marburg (2. leicht aktualisierte Auflage)

Schneidewind, U.; Singer-Brodowksi, M. (2015): Vom experimentellen Lernen zum transformativen Experimentieren. Reallabore als Katalysator für eine lernende Gesellschaft auf dem Weg zu einer Nachhaltigen Entwicklung. In: Zeitschrift für Wirtschafts- und Unternehmensethik. Jg. 16 (1)

Schneidewind, Uwe; Singer-Brodowksi, Mandy; Augenstein, Karoline (2016a): Sustainability and Science Policy. In: Heinrichs, Harald; Martens, Pim; Michelsen, Gerd; Wiek, Arnim (Hrsg.): Sustainability Science. Springer Spektrum: Berlin; Heidelberg, S. 149-160

Schneidewind, U./Siebenhüner, B./Barth, J./Goldschmidt, N./Graupe, S./Korbun, T./Petschow, U./Priddat, B./Reichel, A./van Treeck, T./Zweynert, J. (2016b): Transformative Wirtschaftswissenschaft, in: Ökologisches Wirtschaften 2/2016 (in Vorbereitung).

Scholz, R.W. (2000): Mutual learning as a basic principle of transdisciplinarity. In Scholz, R.W.; Häberli, R.; Bill, A.;Welti, M. (Eds): *Transdisciplinarity: Joint Problem-solving among Science, Technology and Society. Proceedings of the International Transdisciplinarity 2000 Conference. Workbook II: Mutual Learning Sessions*. Haffman, Zürich, pp. 13-7.

Scholz, R. W. (2011): Environmental Literacy in Science and Society. From Knowl- edge to Decisions. Cambridge University Press, New York 2011.

Scholz, R.W. and Tietje, O. (2002), Embedded Case Study Methods: Integrating Quantitative and Qualitative Knowledge, Sage, Thousand Oaks, CA.

Scholz, Roland W.; Lang, Daniel J.; Wiek, Arnim; Walter, Alexander I.; Stauffacher, Michael (2006): Transdisciplinary case studies as a means of sustainability learning: Historical framework and theory. In: International Journal of Sustainability in Higher Education 7 (3), S.226-251. DOI: 10.1108/14676370610677829

Schoolman, Ethan D.; Guest, Jeremy S.; Bush, Kathleen F.; Bell, Andrew R. (2012): How interdisciplinary is sustainability research? Analyzing the structure of an emerging scientific field. In: Sustainability Science, 7, 67–80

Schot, J.; Geels, F. W. (2008): Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis and Strategic Management*. 20:5, 537-554.

Segalas, J, Ferrer-Balas, D, Svanstrom, M, Lundqvist, U & Mulder, KF 2009, 'What has to be learnt for sustainability? A comparison of bachelor engineering education competencies at three European universities',*Sustainability Science*, vol. 4, no. 1, pp. 17–27.

Sipos, Yona; Battisi; Bryce; Grimm, Kurt (2007): Achieving transformative sustainability learning: engaging head, hands and heart. In: International Journal of Sustainability in Higher Education, Vol. 9 (1), S. 68-86. DOI: 10.1108/14676370810842193

Spaapen, Jack; van Drooge, Leonie (2011): Introducing 'productive interactions' in social impact assessment. In: Research Evaluation, 20(3), September 2011, pages 211–218 DOI: 10.3152/095820211X12941371876742;

Stake, Robert E. (2005): Qualitative case studies. In: Denzin, Norman K.; Lincoln, Yvonna S. (Hrsg.): The sage handbook of qualitative research (3. Ausgabe), Sage-Publications: Thousand Oaks, S. 443–466.

Stauffacher, M.; Walter, A.I.; Lang, D.J.; Wiek, A.; Scholz, R.W. (2006): Learning to research environmental problems from a functional socio-cultural constructivism perspective. In: International Journal of Sustainability in Higher Education 7 (3), S. 252-275. DOI: 10.1108/14676370610677838

Sterling, Stephen (2010): Learning for resilience, or the resilient learner? Towards a necessary reconciliation in a paradigm of sustainable education. In: Environmental Education Research 16 (5-6), S. 511-528. DOI: 10.1080/13504622.2010.505427

Sterling, Stephen (2011): Transformative Learning and Sustainability: sketching the conceptual ground. In: Learning and Teaching in Higher Education 5, 2010-11, S. 17-33. Download unter: www2.glos.ac.uk/offload/tli/lets/lathe/issue5/Lathe_5_S%20Sterling.pdf (letzter Zugriff: 11.03.2015)

Steffen, W./Rockström, J./Cornell, S./Fetzer, I./Biggs, O./Folke, C./Reyers, B. (2015): Planetary Boundaries: Guiding human development on a changing planet. Science 347 (6223).

Strohschneider, P. (2014): Zur Politik der Transformativen Wissenschaft. In: Brodocz, A., Herrmann, D., Schmidt, R., Schulz, D., Schulze-Wessel, J. (Hrsg.): Die Verfassung des Politischen. Festschrift für Hans Vorländer. Wiesbaden, S. 175–192

Thomas, Jim (2015): Constructing a 'futurology from below': a civil society contribution toward a research agenda. In: Journal of Responsible Innovation 2(1); S. 92-95

UNECE 2012, *Learning for the future. Competencies for EDS*. Available from: http://www.unece.org/fileadmin/DAM/env/esd/ESD_Publications/Competences_Publication.pdf

UNESCO (2014): Shaping the future we want: UN Decade of Education for Sustainable Development (2005-2014). Final report. UNESCO: Paris. Download unter: www.unesco.org/new/en/unesco-world-conference-on-esd-2014/esd-after-2014/desd-final-report/

van den Bosch, S. J. M.; Rotmans; J. (2008): Deepening, Broadening and Scaling Up: a Framework for Steering Transition Experiments. Essay 02. (Extern rapport). Delft; Rotterdam: Knowledge Centre for Sustainable System Innovations and Transitions (KSI).

Vare, Paul; Scott, William (2007): Learning for a Change: Exploring the Relationship Between Education and Sustainable Development. In: Journal of Education for Sustainable Development 1 (2), S. 191-198. DOI: 10.1177/097340820700100209

Von Schomberg, R. (2011): Towards Responsible Research and Innovation in the Information and Communication Technologies and Security Technologies Fields. European Commission Services, Directorate General for Research and Innovation. Luxembourg: Publication Office of the European Union.

Von Wissel, C. (2015): Die Eigenlogik der Wissenschaft neu verhandeln. Implikationen einer transformativen Wissenschaft. In: GAIA, Vol, 24 (3), S. 152-155.

Wagner, F., A. Grunwald. 2015. Reallabore als Forschungs- und Transformations- instrument. Die Quadratur des hermeneutischen Zirkels. *GAIA* 24/1: 26–31.

Wals, Arjen (1994) 'Action Research and Community Problem-solving: environmental education in an inner-city', Educational Action Research, 2: 2, 163 — 182

WBGU (German Advisory Council on Global Change) (2011): World in Transition—A Social Contract for Sustainability (Berlin: WBGU); Available at: http://www.wbgu.de/ en/flagship-reports/fr-2011-a-social-contract/.

WBGU (German Advisory Council on Global Change) (2014): Climate Protection as a World Citizen Movement, Special Report 2014, Available at: http://www.wbgu.de/en/special-reports/sr-2014-climate-protection/

WBGU (German Advisory Council on Global Change) (2016): Humanity on the move: Unlocking the transformative power of cities: Summary. Berlin: WBGU. Available at: http://www.wbgu.de/en/flagship-reports/fr-2016-urbanization/

Weinert, F.E. (2001), 'Concept of Competence: A Conceptual Clarification' in Defining and Selecting Key Competencies, eds DS, Rychen & LH, Salganik, Hogrefe & Huber, Seattle, pp. 45-66.

Wehling, P. (2012): From invited to uninvited participation (and back?): rethinking civil society engagement in technology assessment and development. In: Poiesis Prax (2012) 9:43–60 DOI 10.1007/s10202-012-0125-2

Wheeler, G., Bergsman, K., Thumlert, C. and Kelly, B., 2010. 'Sustainable Design Project Teacher Manual'. Olympia, WA: Office of Superintendent of Public Instruction. http://www.k12.wa.us/environmentsustainability/pubdocs/sdpmanual2010.doc

Wiek A.; Withycombe, L.; Redman, C. L. (2011): Key competencies in sustainability: a reference framework for academic program development. In: Sustainability Science 6 (2), S. 203-218. DOI: 10.1007/s11625-011-0132-6

Wiek, A.; Kay, B. (2015): Learning while transforming: Solution-oriented learning for urban sustainability in Phoenix, Arizona, In: Current Opinion in Environmental Sustainability 16:29-36

Wiek, A.; Lang, D. J. (2016): Transformational Sustainability Research Methodology. In: Heinrichs, H.; Martens, P.; Michelsen, G.; Wiek, A. (Hrsg.): Sustainability Science: An Introduction. Springer: Dordrecht u.a., S. 31-41

Wiek, A.; Ness, B.; Schweizer-Ries, P.; Brand, F. S.; Farioli, F. (2012): From complex systems analysis to transformational change: a comparative appraisal of sustainability science projects, in: Sustainability Science, 7,2: 5-24.

Wiek, A.; Bernstein, M.J.; Foley, R.W.; Cohen, M.; Forrest, N.; Kay, B.; Withycombe Keeler, L. (2016): Operationalising competencies in Higher Education for Sustainable Development. In: Barth, M.; Michelsen, G.; Rieckmann, M.; Thomas, I. (Hrsg.) (2016): Routledge Handbook of Higher Education for Sustainable Development. Routledge: Abingdon/ New York, S. 241-260

Wiek, A.; Talwar, S.; O'Shea, M.; Robinson, J. (2014): Toward a methodological scheme for capturing societal effects of participatory sustainability research: In: Research Evaluation 23 (2014) pp. 117–132.

Wittmayer, J. M.; Schäpke, N. (2014): Action, research and participation. Roles of researchers in sustainability transitions. In: Sustainability Science. DOI 10.1007/s11625-014-0258-4

Yin, Robert K. (2003): Case study research: Design and methods (3. Auflage). Sage Publications: Thousand Oaks.